Time varying volatility transmission: the case of emerging equity markets in Asia and Latin America, 1984 – 2004

By

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Abstract

Using a multivariate BEKK GARCH model, we investigate volatility transmission i.e. spillover effects within and between emerging equity markets in Asia and Latin America. Our approach allows cross-border spillover effects to vary over time and we break the time series of market returns into four distinct time intervals which correspond with periods of equity market segmentation, liberalisation, financial crisis, and economic recovery. Generally, volatility transmission is time varying in emerging markets but it does not necessarily increase following equity market liberalisation. Our estimates suggest there are some differences in the evolution of volatility transmission between Asian and Latin markets. However, we find evidence of cross-border interdependencies between Asian and Latin equity markets.

Keywords: equity markets, integration, interdependence, volatility transmission, spillover, GARCH, BEKK representation, Asia, Latin America

JEL classification: C32, G15, F36

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1. Introduction

The liberalisation of national financial systems has been one of the most important policy objectives for more than a quarter of a century. Spurred by a positive causal relationship between a country's level of financial development and its rate of economic growth, policymakers deregulated banking systems and equity markets albeit at varying pace and almost not simultaneously. One outcome of this process is the integration of national financial markets with global financial markets; however, the level of integration remains open-ended since many, mostly, emerging markets are not yet fully integrated into global financial markets. Nevertheless, most emerging markets now allow, indeed encourage, foreign investment and permit national corporations to raise finance in international markets. Data from the World Federation of Stock Exchanges show that global equity market capitalisation stood at $31,112,142 million at the end of December 2004, which is around 250% higher than at year-end 1990.[1] Similarly, US Treasury International Capital System data show US investors' net purchase of foreign equities equalled $5,398 million in December 2004 compared with $98 million and $19 million at the beginning of 1984 and 1977, respectively.[2] Given the increasing inter-linkages between national financial markets brought about by trade and financial liberalisation, our intention is to investigate volatility transmission in stock market returns within regional emerging markets in Asia and Latin America, and across Asian and Latin markets.

Equity market integration is likely to increase the covariance of returns across borders. As noted by Karolyi and Stulz (1996), an increase in covariance will affect the volatility of portfolios and the price of assets. *A priori* volatility may increase because greater covariance reduces the opportunities for investors to diversify their portfolios internationally. Eun and Shim (1989, p. 242) explain that ' … unexpected developments in international stock markets seem to have become important "news" events that influence domestic stock markets'. That events in one equity market may produce significant reactions in another market is termed stock market interdependence or spillover effect. Historically, the correlation between emerging market returns and international returns tended to be low which presented investors with significant opportunities for portfolio diversification. However, recent empirical studies find correlations are time-varying (Bekaert and Harvey, 1997), yet there is no clear increase in the co-movement of returns (Bae et al, 2003; Karolyi, 2003) though correlation among emerging markets is reported to have increased (Bekaert and Harvey, 2002).

The characteristics of emerging equity markets are different from developed markets, for instance, the former tend to smaller and less liquid. Similarly, emerging market equity returns also differ from their developed counterparts. Generally speaking, mean returns in emerging markets tend to be higher; they have low correlations with global markets; emerging market returns are more predictable; and their volatility is higher (Bekaert and Harvey, 1997). A leading question is why volatility is so different in emerging markets. Volatility has implications for asset allocation decisions. In a segmented market, risk

[1] See http://www.world-exchanges.org.
[2] See http://www.treasury.gov/tic/index.html.

premiums might be directly related to the volatility of returns in that market. Consequently, higher volatility implies higher capital costs; this feature could increase the value of delaying an investment, the so-called option-to-wait. Bekaert et al (2002) find that equity market liberalisation is associated with higher average returns and lower volatility in emerging markets although not in all. Whereas the correlation between returns in emerging markets and global markets tends to increase after liberalisation, the correlation remains fairly low suggesting potential diversification benefits still exist in emerging market equities.

The aim of this paper is to identify significant cross-border volatility transmission or spillover effects across emerging markets during four time intervals that proxy for distinct changes in government policy and equity market structure; financial sector booms; financial crises; and recovery. Our objectives can be stated as follows. Does equity market liberalisation foster market integration? Are cross-border spillover effects exacerbated during periods of financial crisis? Is there evidence to suggest the volatility of equity markets in Asia and Latin America are linked?

In order to tackle these issues, we model volatility transmission or spillover effects within and between emerging equity markets in Asia and Latin America. Our approach is to break the time series into four distinct time intervals which allows us to identify whether spillover effects are time-varying. The first time interval, from January 1984 to January 1992, covers the period before the sample emerging market countries liberalised their equity markets.[3] The second interval runs from February 1992 until April 1997. Our sample equity markets had been liberalised and large international financial flows to Asia and Latin America (following the end of the 1980s debt crisis) were recorded (and which helped to fuel economic booms). Comparing spillover effects between the first two time intervals allows us to gauge whether equity market liberalisation realises greater market integration or interdependence. Some empirical evidence suggests emerging markets become more integrated with global financial markets after equity market liberalisation although not in all cases (Bekaert and Harvey, 1997). Our results can provide further empirical evidence on this issue.

The results from the second time interval may provide some evidence for an increase in volatility transmission from Latin America to Asia following the Tequila crisis. Mexico experienced a currency problem in December 1994 which later transmitted to other Latin economies including Argentina and Brazil. Brazil also experienced the bursting of a credit boom in 1996 whilst Argentina's problems are well documented. Corsetti et al (1998) discuss the behaviour of international investors following the 1994 Tequila crisis and report that several commentators believe that capital outflows from Mexico were destined for Asia.

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[3] Strictly speaking, the cut-off date is determined by the final equity market liberalisation (Korea in January 1992). We use the dates suggested by Bekaert et al (2002) to date equity market liberalisations. These authors report that the level of market segmentation could be variable before equity market liberalisation because other avenues allowed foreign investors to access national equity markets, for instance, country funds.

Similarly, the third time interval (May 1997 to February 2001) allows us to model volatility transmission during an episode of global financial crisis and to identify whether volatility was transmitted from Asia to Brazil as suggested in the literature (see Kaminsky and Schmukler, 1999; Baig and Goldfajn, 2000). To construct the dates for this interval, we first computed the volatility of monthly equity returns according to Karolyi (2001). We find that equity market volatility substantially increases in several Asian markets in May 1997 and recovers to pre-crisis levels in February 2001. Our final interval is from March 2001 to December 2004.

In order to estimate volatility transmission we employ a multivariate BEKK GARCH model. This model allows us to see whether innovations or shocks in equity markets significantly affect the next day returns in other markets. A significant interaction between two markets implies the markets are integrated. We collect daily equity market index for the period between 1st January 1984 and 31st December 2004 for several emerging markets in Asia and Latin America. The emerging Asian markets are Indonesia, Malaysia, the Philippines and Thailand, and the Latin markets are Argentina, Brazil, Chile and Mexico.

By way of preview, we find equity market liberalisation does not necessarily lead to an increase in cross-border spillover effects. However, we do find evidence of significant equity market interactions within and between emerging markets in Asia and Latin America.

The paper is structured as follows. Section 2 discusses the data used in the paper. The volatility transmission literature with specific emphasis on Asian and Latin markets is reviewed in section 3. Section 4 presents the multivariate BEKK GARCH model with the empirical estimates of volatility transmission presented in section 5. Finally, section 6 concludes.

2. Data

We construct daily equity price returns from the stock price index data of selected markets for the period 1st January 1984 to 31st December 2004 using data sourced from DataStream.[4] We calculate US dollar stock price returns and take account of differences in time zone between Asia and Latin America as suggested in the literature (see, for example, Connolly and Wang, 2003). Since our objective is to investigate volatility transmission within and between emerging markets in geographically disparate regions, we select four emerging Asian markets (Indonesia, Malaysia, the Philippines and Thailand) and four Latin American markets (Argentina, Brazil, Chile and Mexico). In order to investigate volatility transmission between Asia and Latin America we select the following group of markets (Brazil, Korea, Mexico and Thailand).

[4] Equity market returns are constructed in the following manner: returns = $\ln (P_t / P_{t-1}) * 100$, where P equals the value of the equity price index on day *t*.

In Table 1 we present basic descriptive statistics of the raw mean returns and standard deviations for each of the four sub-periods. Also, we show returns from a simple buy and hold investment strategy for each time interval. For the full period, 1984 to 2004, the more risky investment (the market with larger standard deviations) realises the highest returns. A buy and hold strategy for Latin American equities produces the greatest return with Mexico offering the best return (323.05%). The best returns in Asia are in Korea (175.78%) and the worst in Indonesia (22.78%). In the first sub-period from 1984 to early 1992, there is less marked difference in the returns offered by Asian and Latin equities with Argentina yielding the highest return from the simple buy and hold strategy (272.24%). The second sub-period coincides with equity market liberalisation and larger capital flow volatility in the emerging markets. However, despite the greater opportunities to invest in emerging markets, the returns are much lower than previously with losses to the buy and hold strategy in Thailand, Korea, and Mexico. The best returns are in Brazil (138.14%), Malaysia and the Philippines (77.91% and 71.47%). As expected, the financial crisis of 1997-98 means the returns for the period from April 1997 to February 2001 are negative for all markets except Mexico (27.44%). The markets hardest hit are Indonesia, Thailand, and the Philippines where losses exceed 100%. Whilst most markets appear to have recovered up to end-2004, the returns on offer tend to be less than pre-crisis. Surprisingly, the best returns are in Indonesia (92.09%) and Thailand (82.34%) followed by Korea (63.73%), Chile (63.36%) and Mexico (62.30%). Investment in Argentina continues to realise losses whilst returns are relatively low in Brazil.

Table 1 here

Table 2 contains three statistics that describe the distribution of the sample equity market returns. For all markets, the sample mean is significantly different from zero. Each return series exhibits significant skewness and kurtosis. The evolution of each return series and its histogram are shown in Appendix 1 and 2. In order to validate the appropriateness of the BEKK GARCH specification we test for the presence of autocorrelation among the returns, squared returns, residuals, and squared residuals. The Ljung-Box Q statistic is employed to detect the autocorrelation at 8, 16, 24, and 32 lags (see Table 3). As the Q statistics are highly significant, we report the presence of autocorrelation at upto 32 lags and suggest the application of the BEKK GARCH model is appropriate.

Tables 2 and 3 here

3. Literature

The importance of stock market volatility is discussed by many authors (see, for example, Karolyi and Stulz, 1996; King and Wadhwani, 1990; Kearney, 2000; and for emerging markets, Bekaert and Harvey, 1997). A summary of the main findings of the literature on stock market volatility in industrial markets notes the transmission of shocks from the US to other global markets (Eun and Shim, 1989); an increase in the intensity of volatility transmission from the US to European and Japanese markets over time (Kearney, 2000; Baele, 2003, Kim et al, forthcoming); greater interdependence within European financial markets (Kanas, 1998; Baele, 2003; Bekaert et al, 2005); the influence of the behaviour of foreign markets on smaller markets (Jochum, 1989) even after controlling for macroeconomic news (Connolly and Wang, 2003); and an increase in spillover effects following stock market crashes (King and Wadhwani, 1990; Kanas, 1998).

A strand of this literature seeks to identify the responsive of financial market integration to major deregulatory events. In the context of European financial market integration, stock market integration is associated with reduced exchange rate uncertainty and the introduction of the single currency (Fratzscher, 2001; Hardouvelis et al, 2002; Baele and Vennet, 2002; Kim et al, forthcoming), monetary convergence, (Fratzscher, 2001; Baele and Vennet, 2002); and business cycle conditions (Baele, 2003). Finally, integration is greater in open economies with relatively low inflation (Baele, 2003). Elsewhere, the removal of capital and foreign exchange controls in Japan in 1980 facilitated closer integration between that country and the US (Gultekin et al, 1989). However, Ewing et al (1999) cannot support the view that the elimination of trade barriers between the NAFTA (North American Free Trade Area) countries caused an increase in the co-movement of the Canadian, Mexican and US stock markets.

The emerging markets literature suggests that economic integration might be a pre-requisite for observed financial market integration. Phylatkis and Ravazzolo (2002) contend that co-movements of dividend growth rates indicate real economic integration, which affects economic growth in other countries through trade relationships and offer support from a study of Pacific-Basin countries (including several developed and emerging Asian economies). A substantial body of literature suggests regional equity markets are integrated in Asia. Manning (2002) claims integration occurred from 1988 to 1990, and 1992 to mid-1997. However, a divergence occurred between 1990 and 1992 and during the 1997 financial crisis. Some empirical evidence suggests the more developed Asian markets in Japan, Korea and Taiwan became more integrated with the US market by 1997. Masih and Masih (1999) expand on the latter point claiming that international equity markets lead developed and emerging Asian markets. Whereas the US is found to lead Asian markets, the contemporaneous co-movement between Asian markets and Japan is greater. Whilst Asian equity markets react to shocks from the US and Japanese markets, the US increased in importance following the 1997 crisis (Tan and Tse, 2002). Nevertheless, the importance of the Japanese equity market in the regional context is noted by Jang and Sul (2002) and Fernández-Serrano and Sosvilla-Rivero (2001). Specifically, the role that trade linkages play in enhancing financial linkages is suggested as a reason for increases in the co-movement of Japanese and regional equity returns; an increased export share to Japan by regional economies, and greater foreign direct investment from Japan to other Asian countries (Johnson and Soenen, 2002). On the contrary, co-movement decreases because of factors such as differentials in inflation, real interest rates and GDP.

The extent of regional integration in Asia is emphasised by Jang and Sul (2002) who point to high correlations between markets in Hong Kong, Singapore, Thailand, and Indonesia. Similarly, Johnson and Soenen (2002, p. 148) report that ‘Australia, China, Hong Kong, Malaysia, New Zealand and Singapore show significant contemporaneous comovement

(5% level) for at least 82% of the years from 1988 to 1998'. Further confirmation of interdependencies between developed Asian equity markets is provided by Leong and Felmingham (2003) who report the interactions between Singaporean, Korean, Japanese, Taiwanese and Hong Kong equity markets increased after the 1997 financial crisis. Ng (2002) provides evidence that emerging Asian equity markets in Indonesia, the Philippines and Thailand have become more closely linked with Singapore, and that generally speaking, the correlation of equity market returns across ASEAN markets increased over a period following equity market liberalisation.

There is mixed evidence surrounding the effects the Asian crisis had on regional and global equity market volatility. Some suggest the crisis was transmitted through volatility spillovers between Asian equity markets and from SE Asia to international markets in the US and Europe (Caporale et al, 2001; Jang and Sul, 2002). Bekaert et al (2005) define contagion to be volatility in excess of what was expected. Their methodology decomposes the increase in equity market correlations into an asset pricing framework in which movements in regional betas with respect to the global market indicates market integration, whilst contagion effects are identified through movements in the residuals. The results suggest that Asian equity markets became more integrated with one another whereas co-movement with the US and global markets reduced. The presence of significant excess correlation of residuals between Asian markets implies that average contagion increased after the 1997 crisis, though there is no evidence of excess correlation with the US residual (see Bekaert et al, 2005).

There is a paucity of studies of volatility transmission across Latin American equity markets. More interest has been stimulated by the prospect that regional trade agreements have for financial market interdependence. Generally, there is support for a leading relationship from US equity markets to Latin markets although the response of Latin markets is not homogenous (Johnson and Soenen, 2003; Pagan and Soydemir, 2000). The extent of the impact of innovations in the US on Latin equity returns appears to be contingent on several, previously noted factors such as trade linkages and exchange rate volatility: co-movement in returns is greater for Latin countries with stronger trade linkages to the US, and less for countries suffering from exchange rate volatility (Johnson and Soenen, 2003); differences in institutional and financial structure can also explain the variability in the impact that US innovations have in Latin markets (Pagan and Soydemir, 2000). Both studies find Mexico's equity market is more responsive to movements in the US although US movements do impact in Argentina, Chile and Brazil. There is evidence to suggest Latin equity markets are becoming more integrated with US markets following the global financial crisis of 1997-1998. Whilst confirming the relationship between Mexican and US markets, Fernández-Serrano and Sosvilla-Rivero (2002) find the Brazilian market is co-integrated with US markets. Furthermore, and since 1998, they find a co-integrating relationship between US markets and equity markets in Argentina, Chile and Venezuela. Barari (2004) supports the view that Latin markets are becoming more integrated with global markets from the mid-1990s onwards. However, Barari makes an interesting point when she observes that Latin markets tended to become more regionally integrated and less globally integrated during the 1980s and early 1990s. On the contrary, Hunter (forthcoming) does not find any evidence to suggest that Argentinean, Chilean and

Mexican equity markets became more integrated with global markets in the post-liberalisation period. This view finds some support from Bekaert et al (2005) who imply that the volatility of returns in Latin equity markets are more influenced by US factors than regional factors.

4. The BEKK GARCH representation of volatility transmission

The ability to forecast financial time series such as stock market returns, inflation and exchange rates varies from one period to another. For instance, forecast errors may be relatively small in one period but large in another and then small in the next period. This suggests the variance of forecast errors varies over time and that autocorrelation is present in the variance of forecast errors. In order to capture autocorrelation in the variance of the forecast error term, Engle (1982) developed the autoregressive conditional heteroskedasticity (ARCH) model. In ARCH models the variance of the disturbance term at time t depends on the squared disturbance term in the previous period. Thus, the variance is conditioned on information available in period $t - 1$, which allows the conditional variance to change over time as a function of past errors leaving the unconditional variance constant. Engle's ARCH process simultaneously models the mean and variance of a time series.

Stock markets are linked through their second moment and it is suggested that models should take this feature into account when modelling time series which are characterised by uncertainty (Engle and Kozicki, 1993). Bollerslev (1986) introduced a generalisation to the ARCH model (GARCH) to take account of the fact that ARCH models tended to require a long lag length. In the ARCH framework, the conditional variance is specified as a linear function of past sample variances whereas the GARCH approach allows lagged conditional variances to enter as well (Bollerslev, 1986). The GARCH (p,q) framework specifies p squared error terms and q past variances. The literature suggests that a GARCH (1,1) process is appropriate for modelling and forecasting the volatility of stock market returns (Engle and Kroner, 1995; Solnik and McLeavey, 2003). A large literature has emerged which proposes several different GARCH frameworks including integrated or IGARCH, exponential or EGARCH, factor or FGARCH, and GARCH-M (in mean).[5]

The multivariate GARCH model was introduced by Bollerslev et al., (1988). In multivariate models, the first conditional variance is a function of its own lag and a function of the conditional variance of the n series as well as the conditional covariance (all lagged). As the number of parameters to be estimated became excessively large some simplifying assumptions were imposed. Bollerslev et al., (1988) propose the diagonal *VEC* model in which variances depend only on own past squared errors and covariances on the own past cross-products of errors. However, the *VEC* model is restrictive in the sense that it requires the positive definiteness of the conditional covariance. The BEKK[6] representation of the GARCH model circumvents the problem of positive definiteness by

[5] For excellent reviews of the ARCH and GARCH literature see Bollerslev et al., (1992), Gavala et al., (2003) and Bauwens et al., (2003).
[6] BEKK stands for Baba, Engle, Kraft and Kroner.

developing a general quadratic form for the conditional covariance equation (Engle and Kroner, 1995).

GARCH models with conditional correlation are employed in the finance literature to examine the patterns of transmission or spillover effects from one market to another. Multivariate GARCH models are commonly used in time-varying (second moment) studies of covariance. In this study, we adopt the BEKK GARCH (1,1) model since the BEKK representation offers several advantages over other model specifications whilst the literature notes that the (1,1) specification is appropriate for modelling and forecasting the volatility of stock market returns.

The conditional expected return equation posits that each market's return is a function of its own lagged returns and the lagged returns of other markets.[7] :

$$r_t = \alpha + \sum_{p=1}^{n} \Phi_p r_{t-n} + e_t, e_t | \Omega_{t-1} \sim N(0, H_t) \qquad [1]$$

Where
r_t is an n x 1 vector of daily returns at time t for each market,
e_t is the error term of the return equation,
α is the constant term in the return equation,
Φ_p is the matrix of coefficients with the p lagged values of r_t,
Ω_{t-1} is the matrix of conditional past information that includes the p lagged values of r_t.
and, the e_t vector is assumed to be normally distributed with the conditional variance-covariance matrix, H_t.

The n x 1 vector of random errors, ε_t is the innovation of each market at time t with its corresponding n x n conditional variance-covariance matrix, H_t. The market information available at time t - 1 is represented by the information set Ω_{t-1}. The n x 1 vector, α, represent long-term drift coefficients.[8] The elements Φ_{ij} of the matrix Φ are the degree of mean spillover effect across markets. The estimates of these elements produce measures of the significance of the own and cross-mean spillover effects between markets. Hence, the multivariate structure allows the measurement of the innovations in mean equity returns of one market on it own lagged returns and the lagged returns of the other markets.

[7] The BIC (Bayesian Information Criterion) or Schwartz criterion is used to determine the optimal number of lags for each returns series in equation [1].

[8] In order to avoid the problems of dealing with normal distributions, the first moment of errors is represented by a Martingale process in the following equation $E(\varepsilon_t) = E(r_t - \mu)$, where μ is the long-term drift component. It is assumed that e_t in equation 1 follows a process of $E(\varepsilon_t)$. This is important for smoothing the series for calculating the conditional volatility of returns according to the data. In this way, we transform the non-linear BEKK GARCH model into a stochastic model.

In the BEKK GARCH model, the variance-covariance matrix of equations depends on the squares and cross-products of innovation ε_t and volatility H_t for each market lagged one period. The model makes sure that the condition of positive semi-definitiveness is imposed on the conditional variance-covariance matrix, which is necessary for the estimated variances to be zero or positive. Other restrictions are imposed. Namely, the off-diagonal elements in A' and B' are restricted to be equal to zero. Hence, each conditional covariance depends on past values of itself and its own lagged squared residuals. The conditional covariance, however, depends on past values of itself and the lagged cross-product of residuals.

The BEKK GARCH model is written in matrix form in equation [2].

$$H_{t+1} = C'C + A'\varepsilon_t{}^{*}\varepsilon_t' A + B' H_t B \qquad [2]$$

Equation [2] may be rewritten in expanded form in equation [3].

$$\begin{bmatrix} h_{11,t+1} & \\ h_{12,t+1} & h_{22,t+1} \end{bmatrix}_t = \begin{bmatrix} c_{11}^{*} & c_{12}^{*} \\ c_{21}^{*} & c_{22}^{*} \end{bmatrix} * \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \end{bmatrix} * \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} * \begin{bmatrix} \varepsilon_{1,t} & \varepsilon_{2,t} \end{bmatrix} * \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}$$
$$+ \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} * \begin{bmatrix} h_{11,t} & \\ h_{12,t} & h_{22,t} \end{bmatrix}_t * \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \qquad [3]$$

where,
$h_{11,\ t+1}$ = the volatility for the first portfolio of equities in period t+1,
$h_{22,\ t+1}$ = the volatility for the second portfolio of equities in period t+1,
$h_{12,\ t+1}$ = the volatility spillover from the second portfolio of equities to the first portfolio of equities in the period t+1.
c_{11} = the constant coefficient for the first portfolio of equities in period t,
c_{12} = the constant coefficient for the volatility spillovers between the two portfolios of equities in period t, and
c_{22} = the constant coefficient for the second portfolio of equities in period t.
α_{11} = the squared coefficient of error term for the first portfolio equities in period t.
α_{21} = the coefficient of error transmission from the first portfolio of equities to the second portfolio of equities in period t.
α_{12} = the coefficient of error transmission from the second portfolio of equities to the first portfolio of equities in period t.
α_{22} = the squared coefficient of the error term for the second portfolio of the equities in period t.
b_{11} = the volatility coefficient for the first portfolio of equities in period t
b_{12} = the volatility spillover from the second portfolio of equities to the first portfolio of equities in period t.

b_{21} = the volatility spillover from the first portfolio of equities to the second portfolio of equities in period t.
b_{22} = the volatility coefficient for the second portfolio of equities in period t.
$\varepsilon_{1,t}$ = the error term in the first portfolio of equities in period t,ε_2 is the error term in the second portfolio of equities in period t.

Thus, in the BEKK GARCH (1,1) model shown in equation [3], there are equations for $h_{11,t}$, the conditional variance of equity returns in market 1, $h_{22,t}$, the conditional variance of equity returns in market 2, and $h_{12,t}$, which is the conditional covariance between equity returns in markets 1 and 2. In the first equation, $h_{11,t}$ is a function of lagged squared equity return shocks (innovations) in market 1 ($\varepsilon_{1,t-1}^2$) as well as lagged square equity returns shocks in market 2 ($\varepsilon_{2,t-1}^2$), and the cross-term $\varepsilon_{1,t-1}^2 \varepsilon_{2,t-1}^2$. Thus, we can determine whether the conditional equity market variance is affected by the arrival of new information from both itself and market 2. Our model allows us to investigate information spillover effects between groups of four markets, or in other words, the current returns in market *i* that can be used to predict future returns (one day in advance) in market *j*. Specifically, the presence of significant spillover effects can be identified if the cross-equation terms $\alpha_{12}=\alpha_{21}=b_{12}=b_{21}$ are non-zero.

5. Empirical results

We discuss the empirical estimates of volatility transmission in this section. Specifically, the cross-border interdependencies or persistence in the volatility of returns between markets, the b_{ij} from equation [3] are reported in Panel A of the tables and discussed in the text, whereas the α_{ij}, error transmission, is shown in Panel B for information.

5.1 Volatility transmission across emerging Asian equity markets

The estimates of volatility transmission between the SE Asian equity markets of Indonesia, Malaysia, the Philippines, and Thailand are shown in Table 4. This cohort, and along with Korea, were most severely affected by the 1997 financial crisis. Generally speaking, we observe a higher degree of cross-border equity market interdependence prior to equity market liberalisation compared with the immediate post-liberalisation period. Specifically, there are more bi-directional interactions between markets prior to liberalisation with Malaysia and the Philippines reacting more to cross-border innovations than Indonesia and Thailand. Innovations in the latter two markets cause an increase in the next day returns in Malaysia of 11.86% and 22.69%, respectively, and which are the largest interactions during this time interval. Although the amount of significant cross-border interactions is less following equity market liberalisation, we note that the magnitude of the coefficients which show the response of next day Malaysian returns is much larger and signed oppositely to the previous period. By contrast to the first time interval, next day returns in the Philippines market respond only to innovations from Malaysia (15.71%).

Table 4 here

As expected, volatility transmission in Asia increases in the third time interval (May 1997 to February 2001) compared to the second period. Although the number of uni-directional interactions is greater, there is only one bi-directional interaction, that is, between Thailand and Malaysia. The magnitude of the coefficients in this period appears to be smaller than previously. In comparison, the significance of cross-border equity market spillovers is much reduced in the final period (from March 2001 to December 2004). What this suggests is that although there is evidence of significant shocks arising in each of the regional markets (see Panel B); these shocks create only a limited number of significant spillover effects in next day returns.

5.2 Volatility transmission across emerging Latin equity markets

Table 5 shows cross-border spillover effects between Argentina, Brazil, Chile and Mexico. Consistent with the above findings for emerging Asian markets, we observe greater spillover effects prior to equity market liberalisation compared with the period immediately after liberalisation. The fact the all but one of the cross-border interactions are bi-directional implies that Latin markets are more integrated than Asia markets in this period. The magnitude of the spillover coefficients in Latin American and Asian markets are fairly similar in the first period. There are some notable interactions; for instance, innovations in Chile cause a fall in next day returns in Argentina by 27.74% compared to 12.91% and 9.63% from Brazil and Mexico, respectively. There is a large and significant interaction from Brazil and Chile to Mexico (23.39% and 19.40%, respectively) and from Mexico and Argentina to Chile (14.66% and 3.27%).

Table 5 here

Unlike in Asia, there is no strong evidence that spillover effects in Latin America are different after equity market liberalisation. Indeed, the number of significant interactions in periods 1 and 2 are comparable in Latin America. We observe, however, an adverse and much larger response of next day returns in Argentina to innovations emanating from Mexico and Chile. This could be representative of the impact the Tequila crisis had on Argentina. Whilst innovations in Mexico depress next day returns in Argentina, they raise next day returns both in Brazil and Chile. Whereas the period of global financial crisis (May 1997 to February 2001) is associated with stronger equity market interdependence in Asia, the opposite is observed in Latin America where cross-border spillover effects tend to weaken although there are very large and negative effects on next day Argentinean returns resulting from innovations in Chile and Mexico, whilst Mexican innovations positively affects next day returns in Brazil and Chile. Similar to Asia, cross-border spillover effects are less visible in the period from March 2001 to December 2004. An interesting observation in this period, however, is that innovations in Brazil significantly affect next day returns in each of the other Latin markets.

5.3 Volatility transmission between emerging Asian and Latin equity markets

We investigate the possibility of cross-border spillover effects between Asia and Latin American markets using returns data from Korea, Thailand, Mexico and Brazil. *A priori* we expect to observe interdependence in two time intervals, February 1992 to April 1997 and May 1997 to February 2001, as a result of the Tequila and Asian crises, respectively. Contrary to expectations, however, we detect bi-directional spillover effects between the two regions over January 1984 to January 1992. Innovations in Mexico, Brazil and Thailand lead to lower next day returns in Korea; innovations in Korea and Brazil lower next day Mexican returns whilst innovations in Thailand raise Mexican returns. Similarly, next day returns in Brazil are lowered by innovations in Mexico and Thailand, and raised by innovations in Korea. Finally, innovations in Korea, Mexico and Brazil positively affect next day returns in Thailand. These latter coefficients are the largest in this sub-sample and suggest that next day returns in Thailand can be raised from 5.45% (from Korea) to 11.54% (from Mexico).

Table 6 here

We find significant bi-directional cross-border spillover from Mexico to Asia (Thailand) between February 1992 and April 1997 (which contains the Tequila crisis). Innovations in the Thai market raise next day returns in Mexico by 3.72% whereas Mexican innovations increase next day returns in Thailand by a much greater 16.6%. Perhaps this finding is not too surprising given the hypothesis reported in Corsetti et al (1998) that investors shifted funds out of Latin America and into Asia following the Tequila crisis of 1994-95. On the contrary, arguments suggesting a contagion effect from Korea to Brazil are not supported by our estimates of volatility transmission for the period that includes the 1997-98 financial crisis. Instead, we find significant bi-directional interdependence between Thailand and Brazil. For instance, innovations in Thai returns lower next day returns in Brazil by 7.39% whilst shocks to Brazilian returns lower next day Thai returns by roughly 1.2%. On the contrary, innovations in Thai returns increase next day Mexican returns by 9.48% though this interaction is uni-directional. During the March 2001 to December 2004 sub-period, there are uni-directional interactions from Thailand to Brazil (15.26%) and from Mexico to Thailand (around 7%).

6. Conclusions

In this paper, we model volatility transmission across and between Asian and Latin American emerging equity markets. Using a lengthy time series of daily returns, we split the sample into periods that represent equity market segmentation, equity market liberalisation and economic boom, global financial crisis, and eventual recovery. Contrary to expectations, we observe regional equity markets in Asia and Latin America to be characterised by the presence of significant cross-border spillover effects prior to equity market liberalisation. Whereas these interdependencies actually weakened in Asia following equity market liberalisation, such a pattern cannot be observed in Latin America where the amount of spillover effects appears not to have changed. The empirical evidence suggests equity market interdependencies increase during episodes of financial crisis especially in Asia.

Our empirical estimates provide support for claims of equity market interactions between Asia and Latin America. Whilst we do find linkages between Mexico and Thailand during 1992 and 1997 we do not find any substantial support for cross-border spillover effects between Korea and Brazil during 1997 to 2001. Somewhat surprisingly, we observe spillover effects between the two regions prior to their equity market liberalisation and relatively few significant linkages in the most recent period.

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Table 1: Mean Equity Market Returns by Sub-Period, 1984-2004, %

	Indonesia	Malaysia	Philippines	Thailand	Korea	Argentina	Brazil	Chile	Mexico
03/01/1984 - 31/12/2004									
Mean	0.0042	0.0244	0.0303	0.0195	0.0321	0.0551	0.0523	0.0530	0.0729
Standard Deviation	2.4729	1.8580	2.0317	1.8699	2.3060	4.0708	4.1249	1.1615	1.9932
Return - buy & hold	22.78	121.15	150.14	107.00	175.78	244.29	286.59	248.80	323.05
03/01/1984 - 31/01/1992									
Mean	0.0234	0.0632	0.1208	0.0771	0.0849	0.2559	0.0680	0.1223	0.2315
Standard Deviation	2.1303	1.6510	2.5853	1.7338	1.9486	7.4120	5.4185	1.5606	1.8568
Return - buy & hold	49.44	100.20	191.55	162.62	179.18	272.24	143.49	161.98	246.35
03/02/1992 - 30/04/1997									
Mean	0.0469	0.0570	0.0522	-0.0124	-0.0095	0.0181	0.1010	0.0460	-0.0095
Standard Deviation	1.1060	1.2151	1.3961	1.4473	1.5282	2.0078	3.4303	1.0166	2.2094
Return - buy & hold	64.22	77.91	71.47	-17.00	-13.04	24.79	138.14	62.99	-13.05
01/05/1997 - 28/02/2001									
Mean	-0.1830	-0.0814	-0.1101	-0.1210	-0.0541	-0.0256	-0.0188	-0.0395	0.0274
Standard Deviation	4.3340	3.1554	2.3977	2.8009	3.7290	1.9186	3.0470	0.9391	2.3185
Return - buy & hold	-182.98	-81.45	-110.06	-120.97	-54.08	-25.59	-18.81	-39.53	27.44
01/03/2001 - 31/12/2004									
Mean	0.0919	0.0244	-0.0028	0.0822	0.0636	-0.0271	0.0237	0.0632	0.0622
Standard Deviation	1.8559	0.8968	1.1901	1.4432	2.0048	2.4102	2.4342	0.8935	1.3655
Return - buy & hold	92.09	24.49	-2.82	82.34	63.73	-27.15	23.77	63.36	62.30

Table 2: Distributional Properties of Equity Market Returns, 1984-2004

Market	Sample mean	Skewness	Kurtosis
Indonesia	-0.0031***	-0.7968***	50.2855***
Malaysia	0.1830***	-1.5103***	62.0114***
Philippines	-0.1261***	0.3847***	11.2518***
Thailand	0.1678***	-0.2206***	9.9584***
Korea	-0.1422***	0.1047***	11.3306***
Argentina	0.2814***	-5.0017***	126.8157***
Brazil	-0.0977***	0.1327***	27.5115***
Chile	0.0772***	-0.1219***	10.2033***
Mexico	0.1435***	-0.5975***	15.4055***

Table 3: Ljung-Box Q Statistics; 8, 16, 24, 32 lags

	Returns				**Squared returns**			
	Q(8)	Q(16)	Q(24)	Q(32)	Q(8)	Q(16)	Q(24)	Q(32)
Indo	188.33***	236.53***	265.34***	306.81***	915.10***	1223.88***	1529.83***	1669.26***
Malay	99.20***	133.00***	151.30***	170.95***	322.31***	403.09***	423.47***	450.28***
Phils	91.58***	142.75***	159.62***	178.88***	506.24***	803.71***	1056.02***	1303.57***
Thailand	93.70***	127.58***	136.18***	172.71***	282.02***	428.34***	444.11***	486.40***
Korea	55.60***	98.96***	117.52***	153.17***	894.37***	1774.49***	2222.75***	2570.24***
Arg	70.10***	100.35***	124.05***	189.31***	146.66***	243.17***	365.79***	524.57***
Brazil	46.96***	84.22***	102.28***	125.09***	270.01***	309.44***	331.51***	412.39***
Chile	116.54***	219.13***	235.28***	258.07***	256.75***	425.58***	519.95***	597.93***
Mexico	157.11***	195.65***	204.51***	224.23***	481.16***	754.03***	830.45***	922.54***
	Residuals				**Squared residuals**			
	Q(8)	Q(16)	Q(24)	Q(32)	Q(8)	Q(16)	Q(24)	Q(32)
Indo	35.89***	78.47***	108.40***	152.88***	863.88***	1158.33***	1499.19***	1625.28***
Malay	44.67***	77.85***	95.29***	114.42***	442.04***	522.54***	565.84***	602.41***
Phils	16.57***	53.09***	70.65***	90.50***	782.56***	1223.18***	1731.22***	2025.47***
Thailand	16.39***	41.54***	49.98***	80.32***	673.17***	1025.32***	1152.79***	1291.44***
Korea	49.18***	96.73***	113.51***	147.41***	415.69***	1299.95***	1568.44***	2125.14***
Arg	29.56***	58.11***	83.26***	148.88***	121.24***	203.57***	270.15***	522.16***
Brazil	34.36***	67.23***	83.99***	106.36***	398.61***	434.08***	457.26***	548.35***
Chile	27.17***	113.04***	126.63***	152.88***	364.00***	500.28***	613.63***	716.21***
Mexico	24.93***	65.19***	81.21***	104.80***	1454.28***	2498.80***	2757.03***	3071.23***

Note: ***, **, * statistically significant at 1%, 5%, and 10%.

Table 4: BEKK GARCH model of volatility transmission: Asian markets, 1984-2004

Usable Observations 5474								
Panel A:			**Jan84-Jan92**				**Feb92-Apr97**	
	PHIL	THAI	MALAY	INDO	PHIL	THAI	MALAY	INDO
PHIL		-0.0111	0.1028***	-0.0069		-0.0707**	-0.3771**	0.3745
		-0.726	5.225	-0.3007		-1.87	-2.1422	1.4746
THAI	-0.1243***		0.2269***	-0.0893***	0.013		-1.0190***	-0.0917
	-14.1377		9.9972	-3.8835	0.2342		-6.4516	-0.3946
MALAY	0.0087**	-0.0544***		-0.0135	0.1571**	0.0082		-0.1284
	1.9797	-10.8521		-1.4221	2.5455	0.1154		-0.7689
INDO	-0.0409***	0.0168	0.1186***		0.0134	0.0005	-0.3991***	
	-5.1024	1.4559	9.1961		0.4698	0.0173	-10.1245	
		May97-Feb01				**Mar01-Dec04**		
PHIL		0.0093	0.0941***	0.0098		0.0167	-0.0441	0.2301*
		0.4127	2.8341	0.2905		0.4422	-0.7236	1.7337
THAI	0.0824***		-0.0797***	0.0268	0.0368		0.1454**	-0.0253
	6.7646		-2.875	0.8035	1.026		2.0923	-0.2197
MALAY	0.011	0.0214**		0.0179***	0.0209	-0.0244		-0.0704
	1.6372	2.1509		2.6607	1.0836	-1.1117		-0.9697
INDO	0.0253**	-0.0379**	0.033		0.0073	-0.0538***	-0.0306	
	2.0778	-2.1582	1.2573		0.4077	-2.5417	-0.7765	
Panel B:			**Jan84-Jan92**			**Feb92-Apr97**		
	PHIL	THAI	MALAY	INDO	PHIL	THAI	MALAY	INDO
PHIL		0.0093	0.0941***	0.0098		0.0167	-0.0441	0.2301*
		0.4127	2.8341	0.2905		0.4422	-0.7236	1.7337
THAI	0.0824***		-0.0797***	0.0268	0.0368		0.1454**	-0.0253
	6.7646		-2.875	0.8035	1.026		2.0923	-0.2197
MALAY	0.011	0.0214**		0.0179***	0.0209	-0.0244		-0.0704
	1.6372	2.1509		2.6607	1.0836	-1.1117		-0.9697
INDO	0.0253**	-0.0379**	0.033		0.0073	-0.0538***	-0.0306	
	2.0778	-2.1582	1.2573		0.4077	-2.5417	-0.7765	
	May97-Feb01				**Mar01-Dec04**			
PHIL		0.073554***	-0.0357*	0.037888*		0.31749***	-0.2009	0.098349
		3.42308	-1.89661	1.6489		6.50949	-1.75772	1.45436
THAI	0.049455*		0.082511***	0.059483*	-0.26078***		0.128081	0.25215***
	1.88102		2.51739	1.79323	-5.99345		0.97985	2.90955
MALAY	-0.02237	-0.00037		0.079506***	-0.12785***	0.051811**		-0.06183*
	-1.47487	-0.02404		3.2726	-5.70956	2.01589		-1.6456
INDO	0.037888*	0.011962	-0.0153		-0.01459	0.067684**	0.06906	

Note: Panel A shows the persistence of volatility and Panel B the error transmission. The Table is to be read from row to column; information emanating from the market in row *i* spills over to the market in column *j*.
***, **, * statistically significant at 1%, 5%, and 10%.

Table 5: BEKK GARCH model of volatility transmission: Latin American markets, 1984 - 2004

Panel A:		03/01/84 - 31/01/92				03/02/92 -30/04/97		
	ARG	BRA	CHL	MEX	ARG	BRA	CHL	MEX
Argentina		-0.0076	0.0327***	0.0344		0.0313	0.0789***	0.0413***
		-1.0363	5.1140	1.0747		1.2115	6.1611	2.2644
Brazil	-0.1291***		-0.0025	0.2339**	0.1719		0.0730***	-0.0583**
	-4.5533		-0.1911	2.4576	1.0156		4.1137	-2.4116
Chile	-0.2774***	-0.0259*		0.1940**	-0.6813***	0.1299**		0.0204
	-9.2552	-1.9418		2.0727	-2.8840	2.1726		0.5005
Mexico	-0.0963***	0.0100	0.1466***		-0.8113***	0.1742***	0.0861***	
	-2.6167	0.2752	5.9988		-3.9286	2.8430	2.6399	
	01/05/97 - 28/02/01				01/03/01 - 31/12/04			
Argentina		0.0286	-0.0158	0.0260		-0.0262	0.0529	0.0235
		0.5630	-0.5574	0.9539		-0.4007	1.2920	0.6748
Brazil	-0.3560***		0.0423	0.0234	0.1769*		-0.0680*	0.0526*
	-2.8561		1.1179	0.6959	1.7761		-1.7097	1.7973
Chile	-0.8415***	0.0396		0.0619	0.2168	0.0708		-0.0273
	-2.8512	0.2899		0.9950	1.0972	0.5329		-0.3951
Mexico	0.0260	0.2328*	0.1777**		0.5824***	0.1125	0.1250	
	0.9539	1.9469	2.2483		2.9377	0.8312	1.3952	
Panel B:		01/05/97 - 28/02/01				01/03/01 -31/12/04		
	ARG	BRA	CHL	MEX	ARG	BRA	CHL	MEX
Argentina		-0.0232**	0.0268***	0.0363***		0.0740***	-0.0074	0.0103
		-2.2599	3.4888	4.0397		4.7251	-0.4684	1.1041
Brazil	0.1360***		0.0296	0.0144	-0.1480*		-0.0459*	0.0416**
	3.7506		1.6359	0.3810	-1.7479		-1.6666	2.1213
Chile	0.1804***	0.0268		-0.0802***	0.2007	-0.0083		0.0000
	4.6057	1.0341			1.4882	-0.1342		-0.0013
Mexico	0.0658***	0.0403***	-0.0059		0.1881	-0.0163	-0.0258	
	3.1795	2.9376	-0.4129		1.5572	-0.3580	-0.8236	
	01/05/97 - 28/02/01				01/03/01 - 31/12/04			
Argentina		0.0286	-0.0158	0.0260		-0.0262	0.0529	0.0235
		0.5630	-0.5574	0.9539		-0.4007	1.2920	0.6748
Brazil	-0.3560***		0.0423	0.0234	0.1769*		-0.0680*	0.0526*
	-2.8561		1.1179	0.6959	1.7761		-1.7097	1.7973
Chile	-0.8415***	0.0396		0.0619	0.2168	0.0708		-0.0273
	-2.8512	0.2899		0.9950	1.0972	0.5329		-0.3951
Mexico	0.0260	0.2328*	0.1777**		0.5824***	0.1125	0.1250	

Note: Panel A shows the persistence of volatility and Panel B the error transmission. The Table is to be read from row to column; information emanating from the market in row *i* spills over to the market in column *j*.
***, **, * statistically significant at 1%, 5%, and 10%.

Table 5: BEKK GARCH model of volatility transmission: Asian & Latin American markets, 1984 - 2004

Usable Observations 5474								
Panel A:		**Jan84-Jan92**					**Feb92-Apr97**	
	KR	MEX	BRAZ	THAI	KR	MEX	BRAZ	THAI
KR		-0.02675	0.010872***	0.05465***		0.000697	-0.0093	-0.01527
		-1.5541	3.04669	4.0768		0.13442	-1.55331	-0.96445
MEX	-0.04261***		-0.02288***	0.115352***	-0.06091***		0.006909	0.16603***
	-3.7342		-4.43635	13.60697	-2.87588		0.46429	8.61979
BRAZ	-0.04518***	-0.04234**		0.105817***	-0.01165	-0.01228***		0.0
	-7.44064	-2.24813		11.33542	-1.38974	-2.83677		-0.00035
THAI	-0.0215*	0.059213***	-0.04958***		0.005955	0.037166***	-0.01955	
	-1.72077	3.69739	-9.03861		0.27255	4.26337	-1.35434	
		May97-Feb01				**Mar01-Dec04**		
KR		0.0005	0.0173	0.0136		0.0921	0.0985	0.0689
		0.0449	0.88154	1.62338		1.59712	1.06181	-2.17849
MEX	-0.00553		-0.08831***	-0.00538	0.092137		0.513265***	0.1034482***
	-1.03748		-5.10624	-0.61885	1.59712		-6.56961	2.93238
BRAZ	-0.00162	0.015246***		-0.01195***	0.098457	0.060566**		0.0879012***
	-0.73073	3.03038		-3.62458	1.06181	-2.22939		-3.60433
THAI	-0.009	0.094767***	-0.07392**		0.031971	0.006894	0.152593	
	-1.24811	5.34913	-2.17415		1.2446	0.13356	1.90324	
Panel B:		**Jan84-Jan92**					**Feb92-Apr97**	
	KR	MEX	BRAZ	THAI	KR	MEX	BRAZ	THAI
KR		0.034572	-0.02574**	-0.03522*		-0.00481	0.024629	0.00014
		1.33842	-1.9848	-1.7981		-0.41919	1.02962	0.00677
MEX	0.008968		0.0885***	-0.1122***	0.067044		-0.00668	-0.12691***
	0.67074		10.32504	-14.329	1.51971		-0.14965	-3.49306
BRAZ	-0.02455	0.080885**		-0.08225***	-0.00098	0.020355**		-0.00612
	-1.44317	2.32762		-4.91338	-0.04372	2.18458		-0.38233
THAI	0.00408	0.08028***	0.032692**		0.031368	-0.07431***	0.061227	
	0.21393	2.86571	2.5478		0.74193	-4.00953	1.57687	
		May97-Feb01				**Mar01-Dec04**		
KR		-0.03722	0.004609	0.036236		0.15808***	0.083511	0.010323
		-1.12624	0.05571	-1.38313		3.77002	-0.89047	0.25554
MEX	0.030749*		0.2080***	0.025873	0.107852***		0.4176***	0.038861
	1.68123		3.74469	-1.24219	-3.24423		5.92778	-1.22759
BRAZ	0.022573***	0.0815***		0.022219**	0.024463	0.0606**		0.0499**
	2.56037	-5.37538		2.27115	-1.00865	-2.22939		2.15736
THAI	0.036236	0.020299	0.206446**		0.1099***	0.0967**	0.11039	
	-1.38313	0.48111	-2.26296		-3.02667	2.41021	-1.42875	

Note: Panel A shows the persistence of volatility and Panel B the error transmission. The Table is to be read from row to column; information emanating from the market in row *i* spills over to the market in column *j*.
***, **, * statistically significant at 1%, 5%, and 10%.

Appendix 1: Evolution of Share Price returns, 1984-2004

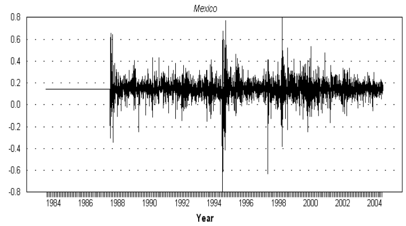

Figure 10.Share Price Return, 1984-2004

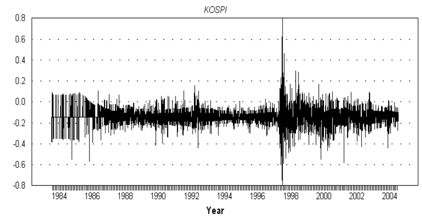

Figure 11.Share Price Return, 1984-2004

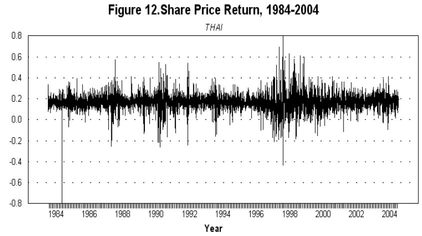

Figure 12.Share Price Return, 1984-2004

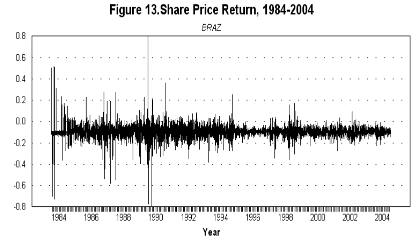

Figure 13.Share Price Return, 1984-2004

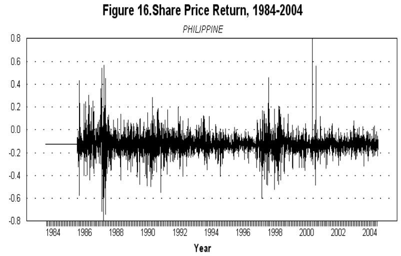

Figure 16.Share Price Return, 1984-2004

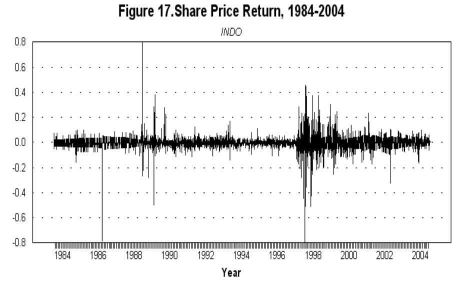

Figure 17.Share Price Return, 1984-2004

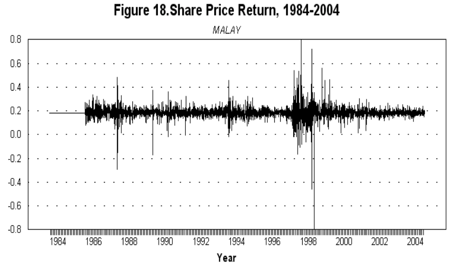

Figure 18.Share Price Return, 1984-2004

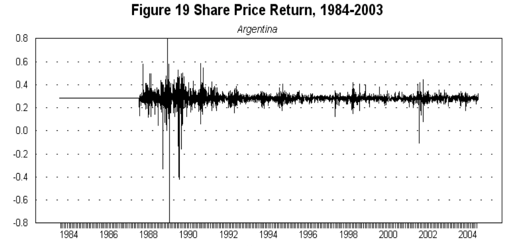

Figure 19 Share Price Return, 1984-2003

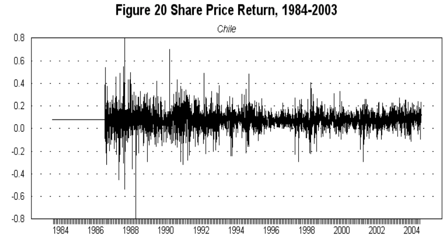

Figure 20 Share Price Return, 1984-2003

Appendix 2: Histograms of Emerging Market Returns

Figure 1.Distributional Propertities of Return

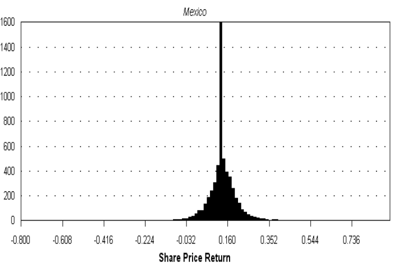

Figure 2 Distributional Properties of Return

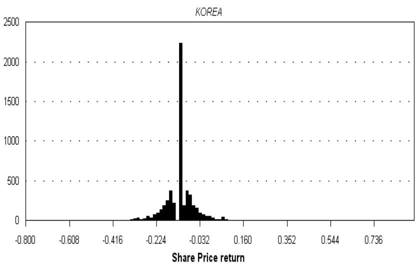

Figure 3 Distributional Properties of Return

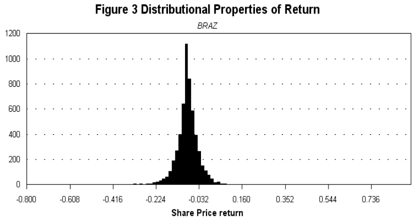

Figure 4 Distributional Properties of Return

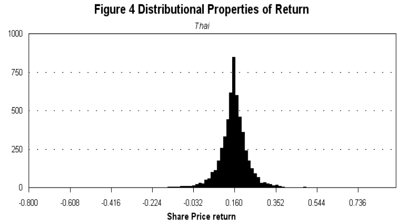

Figure 7.Distributional Propertities of Return

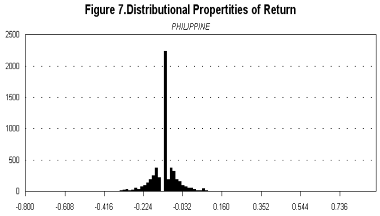

Figure 9 Distributional Properties of Return

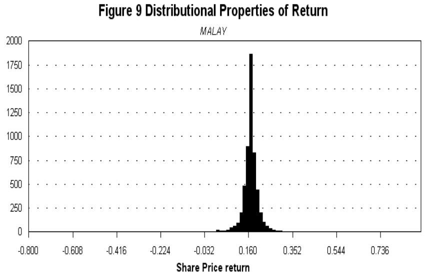

Figure 10 Distributional Properties of Return

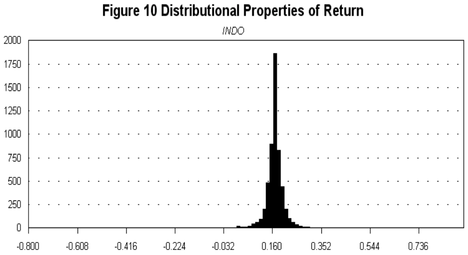

Figure 7 Distributional Properties of Return

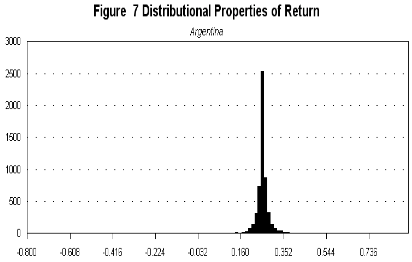

Figure 8 Distributional Properties of Return